Knowledge Based Systems as a Means of Managing Aspects of Datalink Within a Decision Support System for Naval Airborne Early Warning

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Abstract

The future airborne early warning aircraft to be operated by the Royal Navy will consist of an advanced radar driven mission system that will include a datalink: this Datalink, as well as advanced sensors and an expanded role, will impose additional work on the aircrew that operate in the rear of the airborne early warning (AEW) aircraft. Operating the existing mission system is, under certain conditions, considered by AEW aircrew to be at the upper limits of tolerable workload. The deluge of information from these advanced sensor systems and datalink is likely to impact on the aircrew performance and hence overall system performance.

The KBS group of the Defence, Evaluation and Research Agency (DERA) in Farnborough, UK, has been developing Knowledge Based Systems for Decision Support for over a decade. This experience has been applied to the AEW domain with a high degree of success as demonstrated in a laboratory based concept demonstrator. However, previous work had not accounted for the impacts of the AEW aircraft operating within a digitised battlespace.

This paper describes part of a project that was aimed at examining the implications of digitization on the future AEW aircraft and how that would impact the Knowledge Based Decision aids currently being developed. Specifically, the project assessed how datalink would be used and how the information conveyed over datalink could help the aircrew's decisions through greater situation awareness.

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1. Introduction

Naval Airborne Early Warning (AEW) consists of an aircraft with a powerful radar, monitoring the airspace around a force of ships, and scanning for or tracking airborne entities that could pose a threat. Typically this involves either identifying hostile aircraft and directing a friendly fighter to intercept, or identifying a surface to surface missile in time for the force of ships to prepare and adopt defensive positions.

Most navies around the world that have an organic fighter capability (those that have aircraft carriers) also have some form of AEW capability, whether it be fixed wing or helicopter. These aircraft have the capability, should the need arise, to adopt other roles, e.g. anti-surface warfare (ASuW) and land operations support.

In the case of the Royal Navy, AEW is achieved by an AEW aircraft flying along a ‘barrier’ which changes periodically (as the force of ships move) and with which the AEW aircraft must maintain station for the duration of the sortie. The radar is optimised for covering an arc where it is deemed most likely that any threat would originate.

The AEW mission crews are responsible for making the decisions concerning how to deal with airborne threats. In most cases this will involve tasking a combat air patrol (CAP) aircraft to intercept. CAP aircraft are limited in numbers and therefore must be stationed at an optimal point, for short intercept time. Directing the CAP to their optimum position is also the responsibility of the AEW mission crew.

The current RN AEW aircraft have recently been involved in large scale, highly publicised military operations as part of a combined NATO force. This aircraft was designed from the outset for a specific role that did not extend fully into the large multinational arena or into operating with joint and combined forces.

This limited capability has been recognised and is soon to be rectified by a mid-life upgrade that will include new radar and sensors, an enhanced man machine interface (MMI), and a datalink. The inclusion of the datalink, whilst not a result of recent operations, will enable the AEW aircraft to effectively operate in NATO operations as encountered recently.

The UK government Strategic Defence Review (SDR) recognised the Royal Navy’s role in future expeditionary operations. This highlighted the requirement for an organic air capability in terms not just of air defence but also strike. The SDR confirmed the need for a larger fleet aircraft carrier, comparable to the old Ark Royal, of 40,000 tons and capable of carrying up to 50 aircraft.

The aircraft that are to operate from this carrier are also important: the future carrier borne aircraft will be a multi-role fighter not only capable of fulfilling the air defence role but also the presumed strike roles. To support these roles and future carrier led task groups ASW and AEW aircraft will be required.

The future AEW aircraft is likely to be far in advance of the current aircraft employed in this role; advanced radar, greater communications facilities, and a host of optic and electronic sensors will greatly enhance the AEW aircraft capability.

Firm pressures exist to minimise the complement of aircrew in future naval platforms. Aircraft and weapons that are likely to pose a threat to future operations are expected to be faster and stealthier, requiring quicker responses from the aircrew. The combination of this more advanced threat and the increase of information for the small number of aircrew to assimilate, results in a considerably reduced time in which to make a decision. Datalink information alone is expected to add 100 – 200 additional tracks to AEW mission system displays, each of which has to be assessed.

Before the specification for the new AEW aircraft was fully known, it was assumed that the advanced sensors and radar combined with a datalink would provide the aircrew with much more information. To alleviate the problems associated with aircrew workload whilst increasing mission effectiveness, a concept workstation demonstrator was proposed and built [Howells, 1996], as the initial phase of a Technology Demonstration Programme (TDP). This showed the benefits of applying knowledge based decision support (KBDSS) to aid the aircrew.

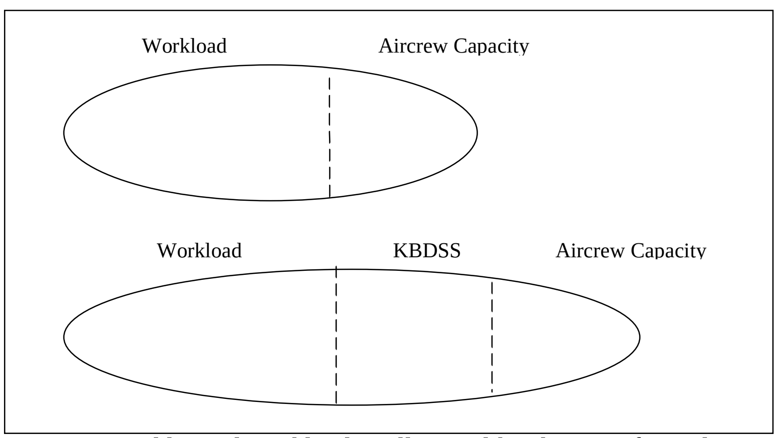

Figure 1. Additional workload is alleviated by the use of an advisory knowledge based decision support aid.

A recent assessment of the laboratory concept demonstrator of the proposed future AEW platform [Davis, 1999] indicated that if aircrew expertise could somehow be encoded into the mission system to provide advice based on the current operating environment and presented to the aircrew, then situation assessment would improve and the tempo of command and control (C2) decision making would quicken.

The KBDSS consists of a knowledge based system that contains encoded AEW aircrew expertise. A KBS is an application that falls under the umbrella of a branch of computer science popularly known as Artificial Intelligence (AI). A KBS is generally made up of several components one of which is a knowledge base. It is within this component that the knowledge is located and accessed. The knowledge was, in the case of the concept workstation demonstrator, acquired through complex, structured, and lengthy Knowledge Acquisition (KA) processes using

acquisition software developed by the Professor of Artificial Intelligence at Southampton University. These processes usually involve studying tactical manuals and intensive and prolonged sessions using the KA software to encompass AEW aircrew expertise.

The acquired knowledge is structured and then represented in the knowledge base in a manner that reflects the way it was acquired. The knowledge base is then manipulated by the various inference methodologies. The intention is that the final KBS will contain and use knowledge in such a way that it mimics the AEW aircrew decision making process. KBS are used because they are considered appropriate for tasks that involve a great deal of knowledge and expertise (this comes from lengthy training programmes and a great deal of experience) and where it is assumed by mission system designers that aircrew expertise will compensate for the partial achievement of expected capabilities of mission systems. KBS are used where Knowledge and expertise cannot be implemented as a series of algorithms.

The KBS group at DERA Farnborough have, for over a decade, applied knowledge based techniques to several naval domains: AEW is by far the most complex so far. To help achieve the goal of implementing complex systems software to assist the development of KBS has been developed. This includes a Knowledge Acquisition toolkit (which was developed in collaboration with academia) and a prototypical implementation environment (which was developed with industry), that includes several knowledge representation schemes as well as providing a real-time multi-agent framework.

2. The AEW Concept Workstation Demonstrator

In 1996, the KBS group, in conjunction with the suppliers of the KA tools and implementation software, began work on a technology demonstrator programme to demonstrate that the tools, methodology (the KBS group advocates the Knowledge Analysis and Design Structure, KADS, methodology [Schrieber, et al., 2000]) and experience gained throughout the previous decade, could be put to effective use in the AEW domain. This domain was chosen because the AEW aircraft upgrade will provide an increase in workload for the AEW aircrew coupled with a demand for minimising manning levels.

An advisory decision support system (based on the knowledge and expertise of aircrew with previous operational experience but with awareness of future technology and tactics acquired as desk officers) acting as an intelligent prompt and mission planner was considered as an effective method for reducing the aircrew workload and increasing the tempo of the decision making processes. A three year programme, undertaken by the KBS group supported by industry, developed the AEW decision support system and demonstrated that a KBS could be implemented over a distributed multi-agent architecture and operated in a soft real time manner [Howells, et al, 1998].

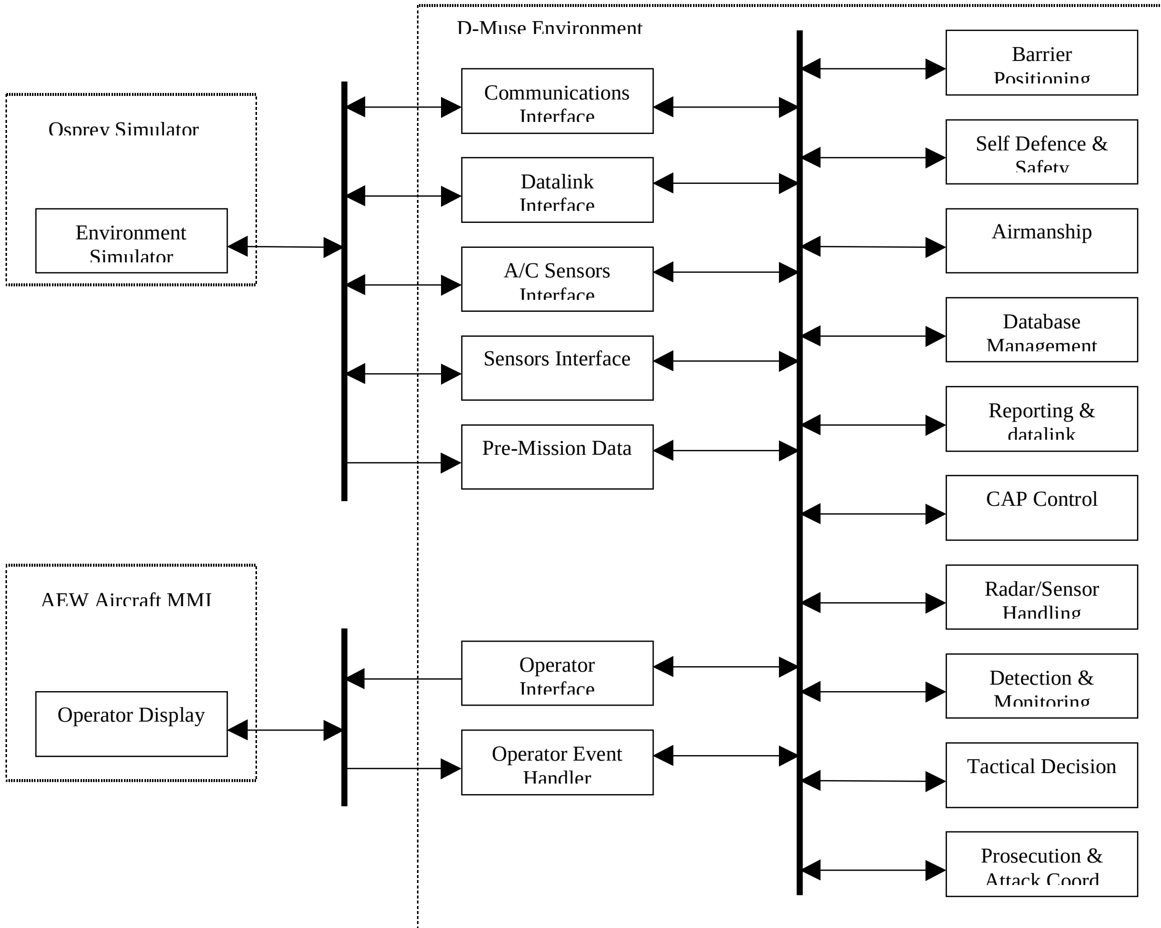

Figure 2. The software/agent architecture of the concept workstation demonstrator [Howells4, et al, 1998].

The architecture of the AEW decision support system is illustrated in figure 2. The domain agents, that is, those dealing specifically with AEW aspects are shown on the right. Additional agents for dealing with data and interfacing are shown in the middle. The final set of agents, dealing with displays and simulators are shown on the left. All of the internal inter-agent communication is based on the knowledge query and manipulation language (KQML) message set [Finin, et al, 1993].

Of the AEW sub-domains described on the right of the diagram, only four were implemented for the demonstrator (these are the more complex sub-domains) due to funding and time constraints. However, those parts of the domain that were represented covered the most significant elements of the overall task and were adequate for the purposes of demonstrating the technology.

Demonstrations interested the AEW aircrew community, some even questioning how such a system could provide advice regarding key decisions so quickly and effectively and in some cases justifying its reasoning. The project is now moving on into an advanced state that will demonstrate the technology in much more realistic and dynamic scenarios [Howells3, 2000]. The future AEW aircraft, likely to encompass a much larger role within amphibious

expeditionary operations, will require a much larger, better-organised knowledge base by generalising the primary responsibilities, a pictorial representation, as shown in figure 3, can be drawn, this describes the interrelation between each area.

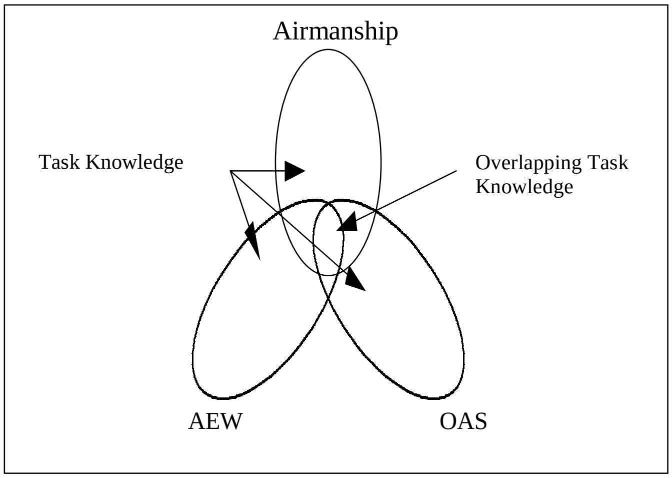

Figure 3. Possible organisation of knowledge for the future AEW aircraft knowledge based decision support system [Howells, 2000].

Airmanship, which includes the general duties undertaken by the aircrew (such as monitoring fuel and relative position) is fundamental as the information provided here directly inputs to the other two tasks. Offensive Air Support (OAS) and AEW are two roles that are likely to be undertaken separately. It is unlikely that the AEW aircrew could cope, even with a KBDSS, with the command and control of different sets of aircraft on different types of mission.

One implication of the mid-life upgrade to the current AEW aircraft is the inclusion of a datalink. The benefits of using a datalink are immense as it affects most tasks the AEW domain. It is quite apparent that datalink will be crucial and should therefore be integrated with a decision support aid in order to take full advantage of the workload reduction in using a DSS.

3. Datalink

The datalink that has been chosen is Link 16 [STANAG]. Link 16, or JTIDS (Joint Tactical Information Distribution System) as it is sometimes referred, is a datalink procured specifically for anti-air warfare with secondary extensions to ASuW. When installed aboard the current AEW aircraft as part of the upgrade it will form the primary means of interaction within a joint or combined operation between air defence platforms.

A significant proportion of information provided by datalink can be influential to the aircrew in decision making. The nature of the message set gives a greater perception of the tactical situation. Until the upgrade of the current AEW aircraft, much of the information that Link 16 can provide is sent through voice communications over soon to be considered obsolete radios. The capability for track reporting is increased as well, one track report currently takes perhaps 10 seconds to communicate whereas several hundred can be communicated in the same time frame using datalink.

Link 16 operates over the JTIDS architecture which is based on time division multiple access (TDMA). This is organised so that entities wishing to send information are allocated time slots, the length of each being 7.8125 m/s. 1536 time slots make up what is known as a frame, which lasts for 12 seconds. Finally, 64 frames form an epoch which lasts for 12.8 minutes and is a complete cycle. Cycles continue until the whole JTIDS network is shut down.

To assist the various systems that operate on a Link 16 network, entities subscribe to network participation groups (NPG). This allows entities with common goals or missions to be grouped together.

The RN is in the process of installing Link 16 terminals aboard various air defence platforms including AEW aircraft, air defence aircraft, air defence destroyers and aircraft carriers. Additionally, the RAF has installed Link 16 aboard its own air defence assets such as E3D Sentry and F3 Tornados.

The use of datalink can benefit the AEW aircraft and additional naval units by providing facilities for passing information including;

- Synchronisation
- Identification
- Relative Navigation
- Surveillance
- Air Control
- Force Orders
- Electronic Warfare
- Fighter to Fighter
- Secure Voice

Much of the information previously described can directly influence decisions made by the AEW aircrew. By using a datalink, the AEW aircraft will be capable of automatic gathering and distribution of information across the battlespace important to mission goals. Two recent studies, [Shadbolt, 1999] and [Farquhar, 2000], conducted for DERA, specifically looked at the direct implications of Link 16 aboard an AEW aircraft. They are:

- Datalink Use. The findings suggested that the actual use of datalink provided much information that required assimilation and understanding by the aircrew to enable to use if constructively to formulate an improved tactical awareness.
- Datalink Administration. This is concerned with datalink specific matters such as how to deal with alerts (alerts are defined within the various NATO agreements as well as specific RN requirements) such as clashes in track numbers, bandwidth, or urgent information that the aircrew must know about.
- Datalink Troubleshooting. The Royal Navy is still gaining practical experience using datalink. Troubleshooting hardware problems that may arise during a sortie could be considered as an initial stumbling block, but this does not detract from the fact that by fixing problems in the short or long term, the aircrew are not able to pay full attention to the tactical situation.

4. Using Datalink Information

Datalink is an automated means of transferring information across the battlespace, a specialised interface will be required to integrate this information into the mission system, since some of it must be used in conjunction with data from on-board sensors such as the aircraft's own radar, information received from off-board sensors must be fused with that from the on-board sensors. To achieve this, the data must explicitly refer to the accuracy, latency and quality of the sensor information being conveyed. It has been assumed that data fusion engines will be capable of this level of fusion of information, although the techniques required are beyond the scope of this paper.

Datalink messages that refer specifically to the states of sending platforms can be easily accommodated within a KBDSS due to the general format of the messages. When these messages are received they can be directed into the KBDSS to update the systems knowledge.

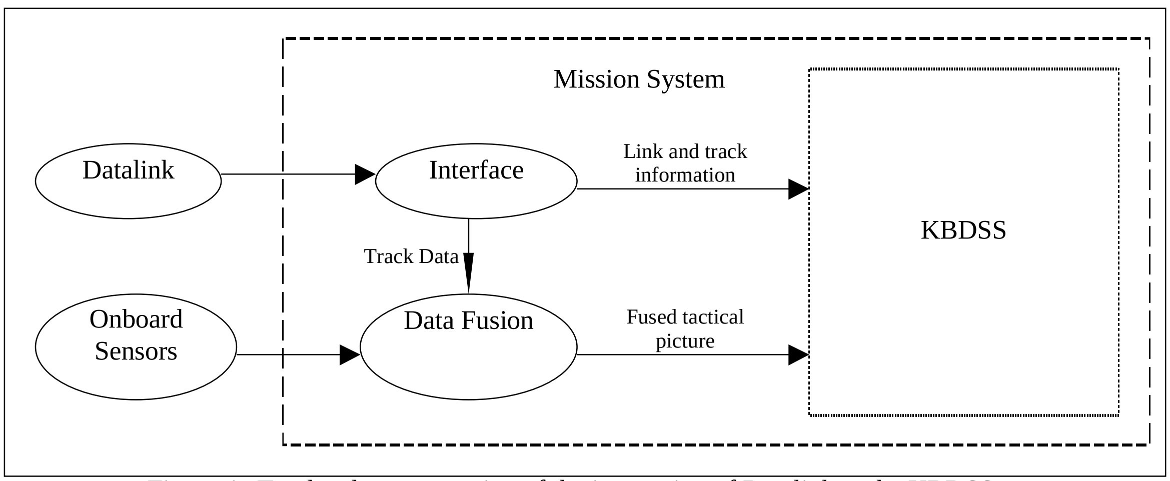

Figure 4. Top level representation of the integration of Datalink to the KBDSS.

Figure 4 illustrates a top-level representation of how datalink could be integrated into a KBDSS. The datalink interface is a knowledge based entity that determines the relevance of each message to the current mission. Therefore, any message that is not particularly relevant to the mission is filtered out and not used within the KBDSS, although there may be cases where some of the information in the message must be used in the data fusion entity. The tactical picture is generated using information provided by the interface as well as information from onboard sensors. All of this information can be fed into the KBDSS for analysis.

Figure 4 does not illustrate the KBDSS dispatching messages. The KBDSS will be expected to formulate messages automatically (i.e. tasking a CAP to intercept or refuel) once approval has been granted by the aircrew. To maximise the bandwidth available to the AEW aircraft, priorities can be associated with each message pending dispatch. The datalink interface is responsible for determining when to send each prioritised message.

There are many different types of message that can be sent over datalink. Each message has a specific purpose for example a J2.2 Air Precise Participant Location and Identification message. This message is to be sent from all aircraft on a Link 16 datalink network to indicate to all other

datalink participants the sending aircraft's position and identification as well as some other aircraft specific information, such as aircraft type and mission. This message combined with another message, J13.2 Air Platform and System Status which provides a comprehensive description of the sending aircraft's state, has the potential to give a near complete description of that aircraft and what it is capable of achieving.

This kind of information was previously available to the AEW aircraft through voice communications and access to onboard databases. In most cases this information would have to be remembered by the aircrew and would be reliant upon continued voice communications for updates.

Messages exist which can provide other forms of information that could be of great use during a mission. One such example is the use of datalink as an extended sensor; by receiving information from other aircraft's sensors the AEW aircraft will be able to put together a more complete Recognised Air Picture (RAP). ESM and other types of sensor data are also available through datalink, the use of this type of information can also add to a complete tactical picture.

Datalink does have the potential to improve the AEW aircrew's situation awareness and tactical decision making, however the information has to be used in a timely fashion to exploit the opportunity of faster and more efficient decisions.

5. Datalink Administration

To effectively use the information provided by a datalink it must be administered efficiently: administration requires the messages and the information conveyed within them to be managed such that they cause little, or preferably no, conflicts or difficulties. For example; track numbers are assigned to all tracks that are known and/or detected, since there are a limited number of track numbers. It is important that each track has its own individual number (no conflicts) and that new tracks are allocated numbers even if this requires re-using older ones. Additionally, some tracks could be allocated more than one track number, in this case the track needs to be correlated or associated.

Another area of administration is concerned with operating with other C2 units that have units operating under them. This requires co-ordination, especially when taking over or relinquishing control of non-C2 units.

Most of the tasks that fall under administration are automated and sequenced in response to given commands. However, problems can occur, for example handing over a CAP aircraft to the control of another C2 aircraft could be inhibited if the C2 aircraft rejects, for whatever reason, controlling responsibility.

Most of what has been described in this section is known as a link alert. For the upgraded AEW aircraft, the man-machine interface contains a database that describes the alerts in accordance with the NATO standard agreements (STANAG) and the Royal Navy's own link administration documents. These documents specify what the interpretation is for given situations. Alerts can

be generated for indicating to the aircrew the state of, or actions taken by, tracks under control or under the surveillance of the AEW aircraft.

Administration is one area of utilising a datalink that is not transparent to the aircrew. It requires direct input and guidance from the aircrew for the whole datalink system to operate effectively. It also requires that the bandwidth available to the AEW aircraft on the link network be maximised. This is important since each unit operating on a link network is allocated a set number of timeslots to transmit data.

6. Datalink Diagnostics

A datalink requires complicated equipment, including the transceiver and link terminal, as well as the software components. The effective use of this equipment requires considerable knowledge, but as with all hardware and software components, they can break down or fail during sorties. To remedy situations where this could happen would require in-depth knowledge of how the whole datalink system works so that the problem can be diagnosed and corrected as soon as is possible.

Aircrew are unlikely to initially have the required knowledge to fix problems that arise whilst flying a sortie. Experience is likely to improve each aircrewmans' abilities with the equipment but this will take a considerable amount of time (dependant on the fault rate combined with the amount of time each of the aircrew spends flying operational sorties)..

7. KBS to Manage Datalink Problems

The KBS group has already developed a knowledge based decision support concept demonstrator for the AEW domain. This is to be further expanded as a multi million pound advanced technology demonstrator programme. More importantly however, datalink, whether it be the information that it is conveying, the administration, or the diagnostics, will take up much of the aircrew's time. The benefits of datalink will not be realised if the AEW aircrew cannot use it efficiently and effectively. It seems obvious to encompass these datalink capabilities that will in the future AEW aircraft platform play a major role.

KBS can be applied to those areas where datalink has an impact on the decision making associated with the different facets of AEW. It can also apply to those areas specifically to do with the datalink that requires a significant level of operating knowledge, and therefore requires additional assimilation time.

As described earlier, using datalink information can affect the AEW aircrew's decision making. This is because the information provided by datalink can be fundamental to the task. However, most of this information is already used, the only difference being the communications medium. Any additional information that does have a bearing on the decision making process would have to be added into the system, enhancing the systems own perception of the track or situation. A short project was undertaken by the KBS group, using their technology demonstrator, to see how the information conveyed by datalink could be integrated into the existing knowledge based decision support concept demonstrator.

In keeping with the demonstrator, it was decided at an early stage to only use messages that conveyed the operational states of a CAP (combat air patrol) aircraft and the operational states of certain surface vessels. This then affects the command and control of own forces in determining intercepts or refuelling. The simple solution to dealing with additional information provided by datalink is to modify the knowledge structures and representation schemes that denote what the system should know about different entities and the different states that will occur during any sortie. This also impacts on the domain knowledge, i.e. what the system should do given specific states, but by using the KADS methodology and the utilisation of a task based decomposition and a structure preserving design principle, modifying domain knowledge is more straight forward.

The first prototype system [Thomas, 2000] was designed so that it could simply receive and manage datalink messages. This involves receiving a message, determining who had sent it, and whether the same sender had sent the message type before. The result of this action was a database that contained one message type from each entity (CAP aircraft, ship, etc) with each message type being updated when each entity sent a new message. This procedure allowed for a near complete representation of each entity using messages only.

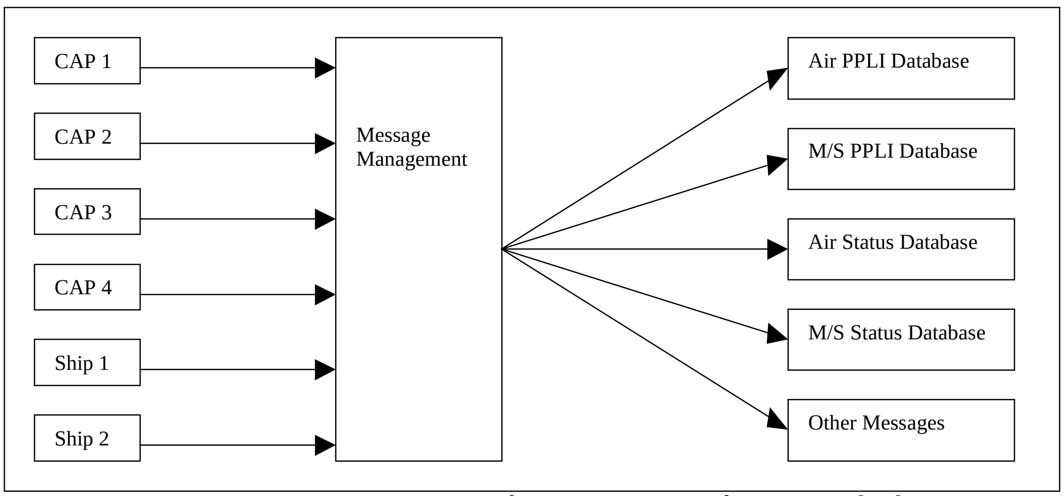

Figure 5. Integrating entity status information into specific message databases.

Figure 5 shows the entities (CAP 1 – 4 and Ship 1 – 2 for example) send all of the appropriate messages and these are received by the message management component. This component basically consists of a production system that contains a set of rules for processing the incoming messages.

There are at least two rules for each message. The first rule simply finds the corresponding message in the appropriate message database. For example, if CAP 1 sends an Air PPLI message, it is received in the Message Management component. The first rule tries to extract from the Air PPLI database the previous Air PPLI message sent by CAP 1. If this is successful the new message overwrites the old message. The second rule places the new message into the appropriate database if there is no previous message. Additional rules can be included to pre-process some aspect of the message if required.

The actual processing of the information provided by the messages occurs when the relevant message databases are updated. The Aircraft Status and Maritime/Surface Knowledge Sources both contain production systems that monitor the updates for changes in the relevant message databases. The various rules fire or activate when specific message fields contain specific values. The rules then apply actions that can have an effect on the KBDSS. Effects can either be changing the sending entity's state or sending internal messages to the MMI.

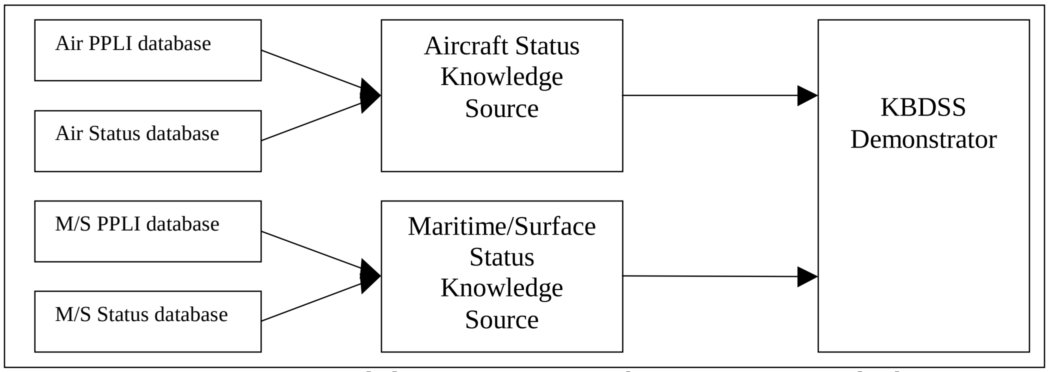

Figure 6. Knowledge sources monitor the various message databases, instigating actions when appropriate within the KBDSS.

Figure 6 diagrammatically shows how this system works. Shortcomings were discovered in the design, namely that each message requires at least two rules. When dealing with many networked aircraft, it is not efficient to apply a forward production system, as this requires a lot of processing that can slow down the overall system. Each of the knowledge sources works on the principle that when there is a specific or general change in the database the rules, or a subset of the rules, fire or activate. The approach adopted here is a general change, where all of the fields are updated when a new message is received. Because of this, rules are trying to fire every time the database is updated which is wasteful if little or none of the information has actually changed.

A second development approach was undertaken which involved building new representations of the entities based on the information provided by the messages. One of the previous lessons was that messages are in their own right a subset representation of the entity that they described. To put these subsets together allowed for more efficiency when it came to reasoning about specific field values. The additional benefit is that messages themselves do not need to be reasoned with when received, since as soon as the message is received all of the required information is extracted for input into the new entity representation. If the messages are being read at this early stage, then specific fields that have changed can be checked against what the system already knows and updated only if necessary.

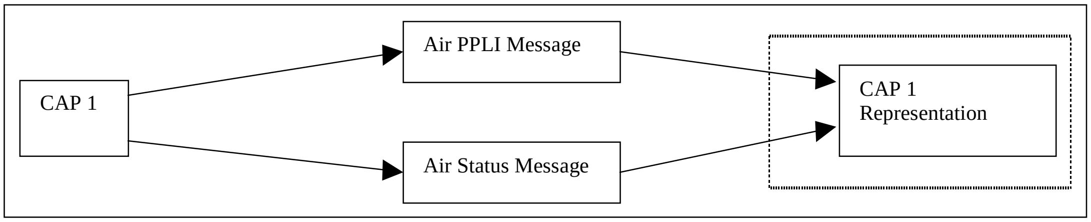

Figure 7. Using messages to generate individual entity representations.

As specific changes are made to the entity representation, the representations that are dealt with by the main component of the system are not being continually updated en-masse.

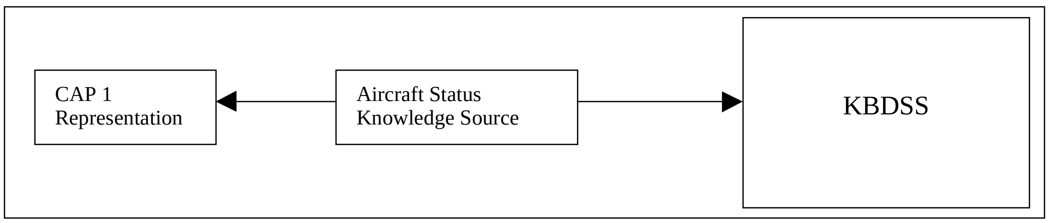

Figure 8. Knowledge sources monitor each entity representation and instigate actions when necessary within the KBDSS.

When there is an update, only the rules associated with the updated field try to fire, this improves the efficiency of the system as well as the speed. Actually determining what information is important is based on KA. If there is an enhancement to the knowledge base that requires additional information from datalink messages, then not just knowledge but additional supporting code must be updated or implemented.

The short project was focussed towards integrating datalink information into a KBS. Managing the datalink is a crucial task as it is concerned with datalink alerts. The study that was undertaken for the KBS group defined datalink alerts as;

- Link-Management alerts.
- Data-management (general/identity) alerts.
- Data-management (IFF and EW) alerts.
- Command and control alerts.
- Aircraft-control co-ordination alerts.
- Aircraft-control alerts.

These different alert types are defined within the various NATO agreements and Royal Navy requirements specifications. It was determined within this study and based upon the specification for the AEW aircraft man-machine interface – developed by the Royal Navy and industry, that alerts are not or should not, be dealt with within a knowledge based DSS, but from within the MMI. This does not mean that alerts, in whatever form, should not form a part of the input to a knowledge based DSS, this is inescapable.

This led to a need to determine how the man-machine interface actually deals with link alerts. Essentially, each alert is stored within a database that displays it to the aircrew in accordance with its associated priority. Due to the number of possible alerts, and the required aircrew responses, it was determined that an additional KBS facility, attached to the man-machine interface, could be used to help deal with prioritising alerts and filtering alerts (in accordance with current mission objectives), it could also provide assistance with regard to resolving the different alerts that occur.

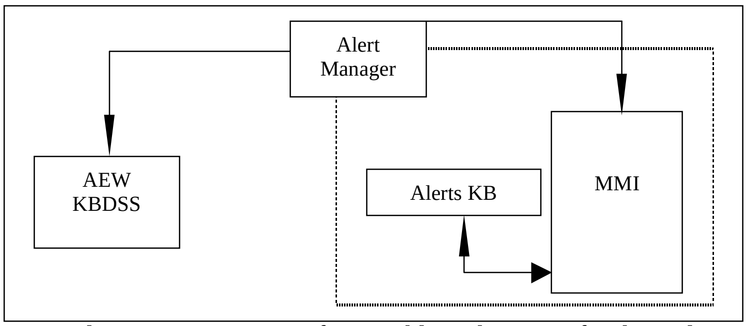

Figure 9. Simplistic representation of a possible architecture for the inclusion an alert manager.

An interesting aspect is that alerts are dealt with in different ways at different times during a mission. This requires that any system that deals with alerts in an intelligent manner can automatically adapt in parallel with changes in the mission. A KBS, attached to the man-machine interface, could be used to deal with alerts separately from the knowledge based decision support system. An important consideration is the overlapping of knowledge between the knowledge base and an alert manager. There is likely to be an overlap of knowledge because some alerts should still be regarded as input to the decision support system.

An additional area identified by the short study was the possibility of a small diagnostic system capable of determining if there is a fault with the hardware and recommending a remedy. This could be interpreted as being important since the level of RN experience with Link 16 is low and will remain low for some time after the upgraded AEW aircraft have been introduced to service. A system that can be used when the datalink hardware breaks down or software crashes can inform the aircrew of the likely cause, allowing for prompt action. In a secondary role, such a system could be deemed useful as a training aid.

8. Results

The short project that was undertaken by the KBS group to integrate information from several message types into the reasoning of the AEW concept workstation demonstrator was limited but successful. Two approaches were undertaken, the second of which was by far more successful than the first but this was hardly surprising since the second approach used a more robust and practical method of representation and inference.

What was apparent was that the datalink information could easily be integrated into a knowledge based decision support system at a superficial level. Since it is likely that datalink information has the potential to have an effect at a much deeper level, it should be obvious that datalink messages, and the information contained within them, should be assumed to be a major input to

the system, possibly on a par with sensor and radar data. Much of this will be discovered during the knowledge acquisition sessions to be conducted during the first 18 months of the advanced research project. It is expected to be difficult insofar as very few RN AEW aircrew have been exposed to datalink.

9. Conclusions

The installation of datalink aboard the current AEW aircraft and its proposed use in the future variant will increase the capabilities that this aircraft has as a C2/C3I platform. This should increase the cases where the aircraft can operate with other NATO forces. Operability with own forces however will be the premium requirement. Much of what needs to be conveyed from the AEW aircraft to the air defence aircraft and ships can be undertaken almost automatically in a fraction of the time that it now takes.

Applying knowledge based decision aids to the future RN AEW aircraft will reduce the workload and assist the AEW aircrew in assimilating the tactical situation. Datalink is a core component of the formulation of the tactical picture and a key component of the tactical decision making process; any decision aid must account for the use of datalink.

The short project that was undertaken by the KBS group aimed to investigate whether information conveyed over datalink could be effectively used by a knowledge based decision support aid. The results were encouraging and have led to the inclusion of the concept into the Technology Demonstrator Programme. Currently it is uncertain how datalink will integrate into the RN AEW concept of operations. Much of the use of datalink is hidden behind the scenes, and only through comprehensive and exhaustive knowledge acquisition will the full implications be known.

The separate ‘link only’ aspects of using datalink are also an important consideration, even if not a part of a decision aid. Effective management of datalink will ensure the smooth running of the datalink network and the faster that it is achieved then the more time there will be for aircrew to focus on the mission. All link alerts must be dealt with quickly and effectively to allow this to happen. The suggested approach of ‘adding on’ a component for specifically dealing with alerts is simple but adheres to the consensus that alerts are not part of the tactical decision making.
The final aspect dealt with by this paper is the possible requirement for datalink diagnostics. Diagnostic knowledge based systems have been around for a long time, and the main advantage of applying such a system to datalink (whether it be separate or integrated) is that it can have a direct impact on the time spent by the aircrew during a sortie fixing hard and software problems that arise.

Knowledge Based Systems, whilst as yet not operationally proven, can be demonstrated in a laboratory or simulation context to show that within the role of decision support, they can effectively deal with the implications of datalink while concurrently providing AEW advice to AEW aircrew. The full potential of datalink will only be realised through experience gained in service. Gaining information superiority is a key enabler in terms of mission success and this is not going to be easily achieved with minimal aircrew personnel without external decision support.

10. The Way Forward

The way ahead for KBS and datalink will be subsumed by the advanced research technology demonstrator programme to be undertaken by the KBS group during FY00 – FY04. The original demonstrator encompassed a significant portion of the AEW domain. A more representative implementation of the domain is intended for the Technology Demonstrator Programme of which the use of datalink is integral.

The plan for the project is to break the whole task, into the three general components, AEW, OAS and Airmanship. Airmanship is to be conducted separately to AEW to provide a small and robust modular system for installation following translation aboard an AEW aircraft for flight test evaluation of the technology. This will encompass the use of datalink for purposes of PPLI (of friendly ships) and possibly force orders (from the command/mother ship).

The larger, more comprehensive AEW task is to be implemented at the workstation level with input from more robust scenario simulators. The risk can be considered quite high for the AEW component due to the expected size of the knowledge base, whereas the airmanship component is expected to be quite small with minimal risk and can be handed over to contractors to translate and flight test.

It is expected that during this programme the advantages of integrating datalink with decision support will be demonstrated.

11. Glossary

AEW	Airborne Early Warning
ARTD	Advanced Research Technology Demonstrator
AsuW	Anti Surface Warfare
ASW	Anti Submarine Warfare
C2	Command and Control
C3	Command Control and Communications
C3I	Command Control Communications and Intelligence
CAP	Combat Air Patrol
DERA	Defence Evaluation and Research Agency
DSS	Decision Support System
EW	Electronic Warfare
JTIDS	Joint Tactical Information Distribution System
KA	Knowledge Acquisition
KADS	Knowledge Analysis and Design Structure
KBDSS	Knowledge Based Decision Support System
KBS	Knowledge Based System
KQML	Knowledge Query and Manipulation Language
MMI	Man-Machine Interface
NPG	Network Participation Group

OAS	Offensive Air Support
PPLI	Precise Participant Location and Identification
RAF	Royal Air Force
RN	Royal Navy
TDMA	Time Division Multiple Access

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